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Knudsen, Thomas; Nielsen, Allan Aasbjerg

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Some safe and sensible shortcuts for efficiently upscaled updates of existing elevation models.

Thomas Knudsen (1) and Allan Aasbjerg Nielsen (2)

(1) Danish Geodata Agency, Copenhagen, Denmark (thokn@gst.dk), (2) National Space Institute, Technical University of Denmark, Lyngby, Denmark (aa@space.dtu.dk)

The Danish national elevation model, DK-DEM, was introduced in 2009 and is based on LiDAR data collected in the time frame 2005–2007. Hence, DK-DEM is aging, and it is time to consider how to integrate new data with the current model in a way that improves the representation of new landscape features, while still preserving the overall (very high) quality of the model.

In LiDAR terms, 2005 is equivalent to some time between the palaeolithic and the neolithic. So evidently, when (and if) an update project is launched, we may expect some notable improvements due to the technical and scientific developments from the last half decade.

To estimate the magnitude of these potential improvements, and to devise efficient and effective ways of integrating the new and old data, we currently carry out a number of case studies based on comparisons between the current terrain model (with a ground sample distance, GSD, of 1.6 m), and a number of new high resolution point clouds (10-70 points/m^2).

Not knowing anything about the terms of a potential update project, we consider multiple scenarios ranging from *business as usual*: A new model with the same GSD, but improved precision, to *aggressive upscaling*: A new model with 4 times better GSD, i.e. a 16-fold increase in the amount of data.

Especially in the latter case speeding up the gridding process is important.

Luckily recent results from one of our case studies reveal that for very high resolution data in smooth terrain (which is the common case in Denmark), using local mean (LM) as grid value estimator is only negligibly worse than using the theoretically "best" estimator, i.e. ordinary kriging (OK) with rigorous modelling of the semivariogram. The bias in a *leave one out* cross validation differs on the micrometer level, while the RMSE differs on the 0.1 mm level.

This is fortunate, since a LM estimator can be implemented in plain stream mode, letting the points from the unstructured point cloud (i.e. no TIN generation) stream through the processor, individually contributing to the nearest grid posts in a memory mapped grid file.

Algorithmically this is very efficient, but it would be even more efficient if we did not have to handle so much data.

Another of our recent case studies focuses on this. The basic idea is to *ignore data that does not tell us anything new*. We do this by looking at anomalies between the current height model and the new point cloud, then computing a *correction grid* for the current model. Points with insignificant anomalies are simply removed from the point cloud, and the correction grid is computed using the remaining point anomalies only.

Hence, we only compute updates in areas of significant change, speeding up the process, and giving us new insight of the precision of the current model which in turn results in improved metadata for both the current and the new model.

Currently we focus on simple approaches for creating a smooth update process for integration of heterogeneous data sets. On the other hand, as years go by and multiple generations of data become available, more advanced approaches will probably become necessary (e.g. a multi campaign bundle adjustment, improving the oldest data using cross-over adjustment with newer campaigns).

But to prepare for such approaches, it is important already now to organize and evaluate the ancillary (GPS, INS) and engineering level data for the current data sets. This is essential if future generations of DEM users should be able to benefit from future conceptions of "some safe and sensible shortcuts for efficiently upscaled updates of existing elevation models".